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Coastal and Ocean Data Assimilation: An introduction to the analysis, interpolation, and assimilation of space-time data

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LONG-TERM GOALS

Our primary goal is to publish a textbook on analyzing, interpolating, and assimilating space-time data. The textbook will be submitted for publication by Cambridge University Press, who has already expressed an interest in publishing the book. This new textbook will be an up-to-date reference on both classical methodlogies and new novel techniques for the analysis, interpolation, and assimilation of space-time data. Many of the new techniques described in this textbook were developed under ONR funding.

OBJECTIVES

Our primary objective is to develop new, multi-scale data assimilation algorithms for both Eulerian and Lagrangian prediction in coastal, ocean, and in transition regions that optimizes the information from measurements with different error and sampling characteristics. In particular, how to both combine and assimilate measurements that measure much different scales of motion in domains dominated by heterogenous, broad-band dynamics. These methods will form the core of the textbook.

APPROACH

Our approaches are based on customizing, for Naval oceanographic applications, the latest developments in signal processing and Bayesian Analysis. In particular, the use of the reduced-order information filter (ROIF) for high-resolution data assimilative modeling, and the re-sampled particle filter (RPF) for the inverse Lagrangian prediction problem.

WORK COMPLETED

The proposed textbook started out as class notes for a graduate course on statistical modeling about 16 yrs ago. Through time and 8 classes, the notes have evolved into a book. The

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book consists of 12 chapters: Linear Algebra (includes Singular Value Decomposition), Probability and Statistics, Model Hierarchy and Error, Linear Systems (ARMA modeling), Parameter Estimation (including Bayesian techniques), Objective Analysis, Multivariate Analysis (includes Principal Component Analysis), Contour Analysis (includes new material on Empirical Orthogonal Contours), Level of No Motion Problem for Ocean Circulation, Variational Techniques, Data Assimilation, and The Real Nonlinear World. Each chapter contains reviews of previous research, detailed descriptions and derivations of the most important methods, a summary of key concepts, and practical recommendations of methodologies for different problems. In addition to the traditional methods presented in the book, there are a number of new, unpublished results, such as the use of a hybrid cross-correlation/Gibbs smoother for feature displacement velocities, hetergeneous basis functions for parsiminuous modeling, and contour-based estimation of non-linear parameters, to name a few, that will be included.
Over 470 pages of the book are written and we are in the process of updating it with some new results on nonlinear filtering and sequential Markov Chain Monte Carlo methods. This requires two new sections in the book on Metropolis-Hastings sampling and nonlinear particle filters. The book is being formatted for Cambridge University Press and the figures are being scanned or drafted, finalized for publication, and embedded into the text.

Part of Ed Ryan's time from this proposal was needed for him to be the webmaster and co-organizer of the 2009 LAPCOD meeting since no other funding was available for this ONR supported meeting. His participation was critical for the success of the meeting. My time for co-organizing the meeting was covered by the U. of Miami.

The latest HYCOM ROIF was improved with the help of A. Srinivasan; it now is the fastest method that is accurate as the other methods tested.

RESULTS

A new textbook with practical, operational methods for interpolating, analyzing, assimilating, and estimating parameters from real-world, noisy, inconsistent, nonstationary, and heterogeneous space-time data.

IMPACT/APPLICATIONS

A new textbook describing novel techniques will have a far reaching impact on the field. The application of Bayesian-based methods for Eulerian field and Lagrangian trajectory prediction, such as the resampled particle filter that can be used for deployment strategies for drifting acoustic sensors and to design Lagrangian-based optimal sampling, is the future of prediction methods for Navy operational needs.

TRANSITIONS

The book will be readily available to all Navy and Navy-funded scientists and students.

RELATED PROJECTS

Many of the methods in the book were developed in collaboration with A. Griffa, T. Özgökmnen, A. Srinivasan, and the HYCOM Data Assimilative Modeling Consortium.

PUBLICATIONS (2008-2009)

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